Glass Transition in a Two-Dimensional Electron System in Silicon I

Dragana Popović, Florida State University, DMR-0071668

Glassy states of matter appear in a wide variety of materials including amorphous solids, spin systems, flux lattices, disordered semiconductors, and macromolecular networks. Since glassy systems do not reach thermal equilibrium on experimentally accessible time scales, their characterization remains a challenge. Thanks to recent experimental advances, there are now several nonequilibrium quantum systems that are accessible to both experiment and theory. Our own work presents the first evidence of glassy behavior in a two-dimensional (2D) electron system realized in semiconductor heterostructures, where glassiness results from the interplay of disorder and electron-electron interactions. Since glass transition takes place near the 2D metal-insulator transition, our results will have important implications for theories of this phenomenon, as well as for understanding strongly correlated, disordered systems in general.

We have measured the conductivity σ of a 2D system in silicon as a function of time t over a wide range of electron densities n_s and temperatures T. The power spectrum of the noise, i.e. of the fluctuations of $\sigma(t)$ (Fig. 1), follows the well-known power law $S \propto 1/f^{\alpha}$. Most remarkably, we find that below a certain, well-defined density n_g, α jumps abruptly from ≈ 1 (ubiquitous 1/f noise) to a large value ≈ 1.8 (Fig. 2), typical of systems far from equilibrium. This sudden jump of α, along with abrupt changes in other spectral features of the noise, indicates a dramatic slowing down of the electron dynamics at n_g, characteristic of glassy systems. Indeed, a more detailed analysis of the noise (so-called second spectra) shows an abrupt change to the sort of statistics characteristic of complicated multistate systems just at the density n_g at which α jumps.

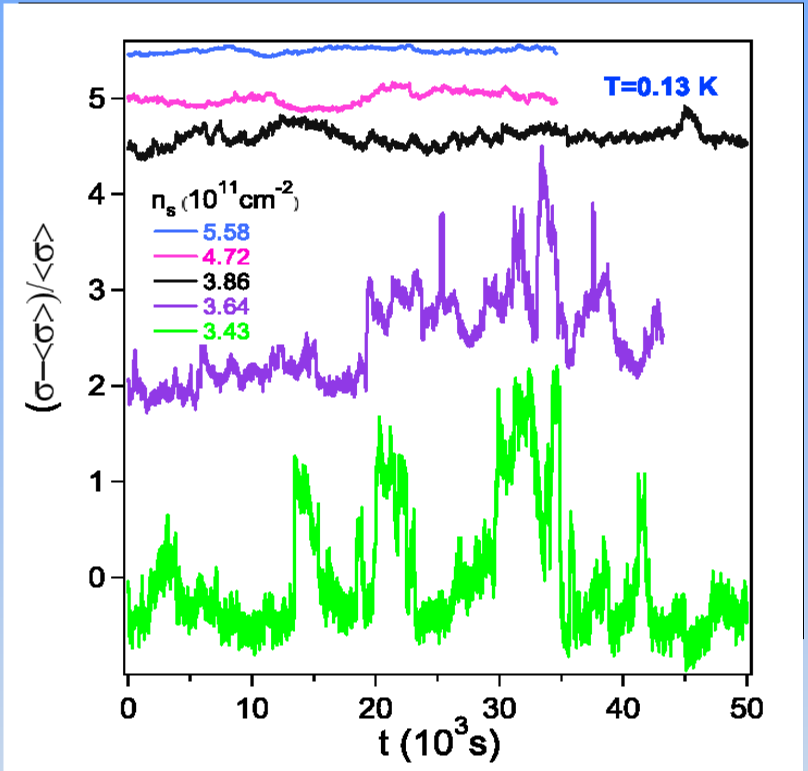

Figure 1. Relative fluctuations of conductivity σ vs. time for different electron densities n_s at temperature T=0.13 K. (<σ>denotes conductivity averaged over time.) Different traces have been shifted for clarity, starting with the lowest n_s at bottom and the highest at top. The size of the fluctuations reaches up to 100%. In addition to rapid, high-frequency fluctuations, slow changes over several hours are also evident.

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Educational:

1 graduate student,
2 post-docs.

Brief summary of outreach activities:

- the PI helped with science demonstrations for the general public at the National High Magnetic Field Laboratory's 8th Annual Open House
- the PI served as a Science Fair judge at FairviewMiddle and Roberts Elementary Schools

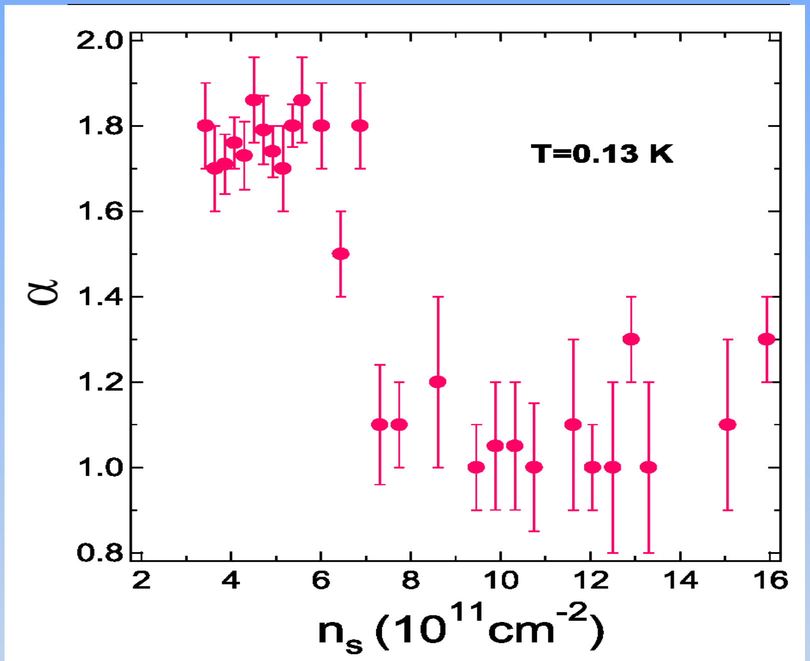

Figure 2. The exponent α, which describes the frequency dependence of the noise power $S \propto 1/f^{\alpha}$, vs. electron density n_s. A sudden jump of α from ≈1 to ≈1.8 indicates a dramatic slowing down of the electron dynamics at $n_g \approx 7 \times 10^{11}$cm^{-2}, which is attributed to the freezing of the electron glass. Such large values of α are typical of systems far from equilibrium.